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Chapter

Climate Change Impacts and Adaptation in Agricultural Sector: The Case of Local Responses in Punjab, Pakistan

Muhammad Mumtaz, Jose Antonio Puppim de Oliveira and Saleem H. Ali

Abstract

This study contributes to explore local responses to deal with the impacts of climate change on agriculture sector by looking the case of Punjab, Pakistan. Pakistan's agriculture is facing severe challenges due to the negative consequences of climate change. In this study, we investigate (a) What are the different initiatives taken at planned and autonomous level in Punjab province? (b) What are the drivers behind these initiatives? (c) How these initiatives are being transferred within farmer's community in Punjab and outside Punjab? and (d) What are the challenges for these farmers in adaptation to climate change and governance hurdles in the province? The government has launched massive level awareness campaign in the province. Other important initiatives are institutional capacity enhancement, promotion of climate change research, establishment of linkage with academics, enhancement of capacity building, and involvement of farmers' community in climate adaptation for agriculture sectors. The autonomous adaptation initiatives include changing planting dates, changing crops types, changing fertilizers, and planting shade trees. Planned level adaptation is primarily driven by coordination among the respective departments, engagement with academics, and availability of financial resources. Autonomous initiatives of the province are mainly driven by the previous experiences of farmers, sustainability in agriculture production, and knowledge sharing.

Keywords: adaptation, governance, climate change, agriculture, Punjab

1. Introduction

Climate change is a reality; according to Intergovernmental Panel on Climate Change (IPCC) fifth assessment report, humans are responsible for this unsustainable situation. From future climate change perspective, both human and natural systems are at risk [1]. It is a globally environmental challenge. Developing countries are more at risk due to a lower adaptive capacity and higher resource scarcity [2].

Climate change poses serious threats to Pakistan. Presently, climate change is considered one of the serious crises in Pakistan [3], as it is one of the most vulnerable countries, mostly due to its diverse geographical and climatic features [4]. As such, it has caused various disasters in the form of floods, droughts, and other

natural calamities in the country [5]. In the aftermath of the 2010 floods, one fifth of the country's land area was submerged; it severely damaged the economy and infrastructure, impacted livelihoods of millions of people, and left 90 million people food insecure [6]. Pakistan is among those countries which were badly affected in 2012 due to climate change [7].

Climate change is a great challenge for the agrarian economy of Pakistan [8]. The agriculture sector of Pakistan is highly vulnerable to climate change [9]. Livelihoods of millions of Pakistanis are dependent on agriculture sector which is highly sensitive to climate change [10].

This sector contributes approximately 25% to the national Gross Domestic Product (GDP) and it absorbs about 42% of the labor force [11]. The sector generates over 75% of export revenue and it is the largest employer sector in the country [12]. Agriculture sector in Pakistan faces serious challenges from climate change-induced impacts, i.e., rising temperatures, floods, droughts and yield losses [13]. It is likely the variation in monsoons and increased temperature is a real challenge to the agriculture sector in Pakistan [14].

There are evidences that climate change will continuously pose threats throughout this century despite international efforts to curb greenhouse gas emissions [15]. In order to confront the challenge of climate change many efforts are made around the world. Various climate change policies are established at international, national, subnational, and local levels to address the impacts of climate change. Traditionally, the focus of such policies remained on mitigation instead of adaptation measures despite urgent requirements for adaptation strategies being emphasized [16]. Adaptation actions are important response to climate change as these actions help to reduce the vulnerabilities in the social and biological system [17]. One of the major objectives of adaptation measures is to build the resilient in societies to face climate change [18].

The need for adaptation policies and actions is increasingly recognized [19]. Governments are being forced to rethink their ways to manage climatic impacts and to focus not only on mitigation but also adaptation [20, 21]. Due to increasing public interests, the adaptation policies are being recognized and gaining space on policy agenda [22]. In case of most vulnerable countries to climate change, adaptation is the focus of their strategies to tackle the negative consequences of climate change. Many countries including Pakistan recognize the need to focus on adaptation strategies to effectively address the challenge of climate change.

To manage the potentially fatal issue of climate change, Pakistan responded with various initiatives, mainly on adaptation measures. These initiatives are in the form of climate change policies, implementation frameworks and some other measures. The national climate change policy of Pakistan says, "Adaptation efforts are the focus of this document." Pakistan is ranked in the list of the countries that have the least adaptive capacity due to extreme poverty and lack of physical and financial resources [10].

The subnational governments are key institutions for the effective implementation of climate change related policies. The subnational governments are important to helping curb climate change due to their proximity to the consequences of climate change [22]. Subnational governments in Pakistan have taken multiple initiatives to manage climate change. For instance, in Punjab a massive level awareness campaigns has been launched, establishment of provincial climate change policy, and establishment of linkage among the related departments in the province are some of notable initiatives among others.

Pakistan recognizes the important role of subnational governments/provinces for effective response to climate change. After 18th constitutional amendment in 2010, the responsibility of implementing climate change policies rests with respective provinces/subnational governments in the country. This study is conducted to understand the adaptation governance initiatives for agriculture

sector in the province of Punjab, Pakistan. This province is the major contributor of agriculture sector in Pakistan. The province accounts for 53% of the total GDP in the country. It is noted that agriculture adaptation actions reduce agricultural losses [23]. The subnational government of Punjab is taking adaptation steps to tackle climate change.

The objective of this study is to understand how adaptation to climate change for agriculture sector is happening in Punjab province. The study mainly focuses on the key factors: (a) What are the different initiatives taken at the planned and autonomous level in the province? (b) What are the drivers behind the initiatives (c) How these initiatives are being transferred within farmers' community in Punjab and outside Punjab? and (d) What are major challenges for these farmers in adaptation to the climate change and governance hurdles in the province?

The study contributes to the literature on climate adaptation governance and adaptation policies for the agriculture sector at subnational level by exploration of hidden adaptation measures at subnational level. It essentially contributes to explore the drivers behind adaptation measures in the province. Moreover, it contributes by identifying policy needs and research gaps for climate adaptation at subnational level. Additionally, the study provides some replicable lessons for other developing countries while devising adaptation policies and action plans at subnational levels.

2. An overview of adaptation strategies

The scientific community concluded with a strong consensus that climate is changing. According to the fifth report of IPCC [24], climate change is taking place in the world and developing countries are especially expected to suffer more, compared to the developed world.

To manage the consequences of climate change, two fundamental societal response options emerged in the form of mitigation and adaptation [25]. Füssel [26] maintained that mitigation and adaptation are complementary rather than mutually exclusive. Historically, the focus to address climate change remained on mitigation measures [27]. However, a shift emerged and it became widely accepted that mitigation alone is unlikely to be sufficient to cope with climate change [28].

Adaptation to climate change is getting much attention in the scientific and policy debate [29, 30]. Adaptation is defined as: "adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts" [31]. According to Stern, "adaptation will be crucial in reducing vulnerability to climate change and is the only way to cope with the impacts that are inevitable over the next few decades" [32].

Many countries have set their strategies to cope with climatic event at national, provincial, state, district and local levels [33]. The first time that the dilemma of adaptation for developing countries was recognized, was in 2001 at the Seventh Conference of the Parties in Morocco [34].

The important role of climate change adaptation as a policy is well considered and recognized internationally [35]. For instance, Article 4.1b of the United Nations Framework Convention on Climate Change [36] states that parties are "committed to formulate and implement national and, where appropriate, regional programs containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change." Likewise, Article 10 of Kyoto Protocol also emphasized the promotion of adaptation and the incorporation of technological advancements for adaptation to overcome climate change [30]. Furthermore, in 2007 during the United Nations Conference on Climate Change in Bali, the need to enhance actions on adaptation by Parties to the Convention was emphasized (UNFCCC [37]).

Adaptation is essentially important to avoid impacts of climate change otherwise these impacts happen gradually [28]. It has been projected by climate models that there would be more frequent devastating floods, high rainfall events, and heat waves. Therefore, this scenario of climatic impacts necessitates the incorporation of adaptation strategies. Adaptation is considered a promising step to strengthen local capacity to tackle the forecasted and unexpected climatic conditions [38].

In Paris Agreement 2015, the adaptation to climate change is much emphasized. Dessai et al. [38] argued that mitigation alone is not sufficient to address climate change effectively. Therefore, adaptation attempts are made around the world to curb the challenge of climate change.

Pakistan recognizes the importance of adaptation to climate change. Change adaptation strategies are important to deal the issue of climate change in Pakistan (Ali and Erenstein [39]). Pakistan's policy response prioritizes adaptation measures. For instance, national climate change policy is much focused on climate adaptation initiatives. Mumtaz [40] argued that climate adaptation measures are unavoidable for Pakistan keeping in view its high vulnerability to climate change. It is reported that these adaptation measures are important for all major sector including agriculture sector.

3. Climatic impacts on agriculture sector

Agriculture is a sensitive sector to climate change and it is considered among the most vulnerable sectors to the impacts of climate change [35]. Extreme weather conditions and precipitation changes are affecting the crop development, growth and yield of crops [41]. Rise in temperature reduces the grain filling duration, caused the grains sterility and yield reduction [42].

For last few decades high temperature is reported in Asia and the Pacific regions [43]. The agriculture sector in these regions is more vulnerable considering that Asia and the Pacific are responsible for 37% of the total world emissions from agriculture production. Most vulnerable countries in these regions are: Bhutan, Indonesia, Pakistan, Papua New Guinea, Sri Lanka, Thailand, Timor-Leste, Uzbekistan, and Vietnam [44]. It is also reported that agriculture sector may disturb the climate [45]. It is indicated that 14% of nitric oxide and methane is coming from the agriculture sector and 18% is due to deforestation for agriculture use [46].

Agriculture sector is the backbone of the economy of Pakistan. This sector in Pakistan faces serious challenges due to climate change which impacts in the form of rising temperatures, floods, droughts, and yield losses [13]. The continuously occurrence of floods in Pakistan and other climate change impacts is costing the country 14 billion dollars per year, which is around five% of gross domestic product (GDP) to its economy [47].

Agriculture sector feeds food to the fast growing population of Pakistan according to Economic Survey of 2010–2011. Climate change is a great challenge for Pakistan's agrarian economy [8]. Agriculture productivity is affected by various factors including rainfall pattern, variation in temperature, and variation in dates of harvesting and sowing, availability of water, and evaporation along with suitability of land [9]. It is projected with 1°C rise in temperature will cause (6–9%) decline in wheat productivity [48].

To face the risks in agriculture associated with climate change, adaptation is the key factor to address the negative impacts of climate change. Adaptation strategies are important opportunities to tackle climate change effectively and to sustain the crop production [49]. Adaptation is an important policy response to climate change in agriculture sector [31, 35]. The IPCC emphasizes that it is very fundamental for the agricultural sector to adapt to climate change.

During the last two decades, the role of subnational states in the realm of global climate governance has grown significantly [50]. They further pointed out that the role of subnational governments has been extended as influential actors in international climate change policies. It is normal to find subnational governments playing a leading role in climate change policies [51].

The existing literature highlights the role of subnational policies for climate governance. As such, Jörgensen [52] argued that subnational state policies are a key aspect of climate governance and function as laboratories of experimentation which could promote policy change through policy-learning. Jänicke [53] considered that provincial (subnational) and state level activities for climate change have increased significantly in the recent years.

Climate change adaptation poses many complex governance questions and has therefore been called a "wicked problem par excellence" [54, 55]. The "wicked problem" needs comprehensive and proper solutions. Adaptation governance faces many difficulties, hindrances and opportunities involved in dealing with the "wicked problems" [56]. They further argued that due to the novelty and complexity of adaptation governance, a number of fundamental governance dilemmas have to be (re)addressed in developing the governance of adaptation to climate change. For instance, which ministry or agency is responsible for climate policy in general and climate adaptation policy in particular? Are existing divisions of responsibilities adequate for tackling climate adaptation issues?

It is evident that nation states, multilateral and bilateral development organizations, citizen's groups and communities are expected to respond to the negative impacts of a changing climate. There is a consensus in adaptation/adaptive capacity literature that there is a need to build adaptive capacity in the form of free flow of ideas, knowledge and technology, capable institution and government schemes, and other policies for an effective response to climate change [57]. They further highlighted that it is significantly unclear that how this adaptive capacity is actually built or enhanced.

To deal with the complex issue of climate change, equally complex solutions are required which involve several fields of human activity and different stakeholders. Multiple stakeholders, such as civil society, research institutions, universities, private sectors, etc., play an important role in the production of responses to the climate crisis together with governmental representatives [58]. The linkage of subnational/local governments with international networks provides a great potential for the development of effective policies and actions as responses to climate change [59].

Presently, the subnational or local level governments have an important governance role to tackle climate change in general and climate change adaptation in particular. However, there has been relatively little research in the area of adaptation policies especially in developing countries. There are studies in Pakistan which highlight the need for adaptation action but actual field-based studies for adaptation responses to climate change are rare [10]. The need for field-based studies is increasingly recognized as important for better understanding of the local level vulnerability and adaptation responses to climate change [60]. Therefore, this study is important to highlight the responses of subnational governments for climate adaptation.

4. Climate adaptation in Punjab

This study was conducted for the period of November 2016–April 2017. Apart from desk research, 30 in-depth semi-structured interviews were conducted with

relevant stakeholders. These stakeholders include policy experts, government officials, think tanks working in the area, related nongovernmental organizations, academics, ministry of climate change, provincial environmental protection agency, farmer community, civil society, and climate change activists in the province of Punjab.

Punjab is geographically located approximately at 30,000 N, 70,000 E in the semi-arid lowlands zone [61]. It is the most populous and second largest province of Pakistan. Punjab is a fertile agricultural region which holds an extensive irrigation network and plays a leading role in the development of the economy [62]. The province accounts for 56.2% of the total cultivated area, 53% of the total agricultural gross domestic product and 74% of the total cereal production in the country [63, 64]. Punjab mainly contributes for agricultural sector in the percentage of land (57.2%) in agricultural sector and the percentage share (53%) of Pakistan's agricultural gross domestic product [65]. Agriculture sector in Punjab is facing the impacts of climate change. Below is the map of Pakistan, highlighting light green portion as our case of study that is Punjab province (**Figure 1**).

During the last decade or so, climate change adaptation gained a space on policy agenda. Subnational governments, being closer to the locale of climatic impacts, play a key role in the effective implementation of climate change policies. In the case of Pakistan, the implementation of climate change and other related policies rests with subnational governments. In this section, we analyze the adaptation strategies in Punjab Province. **Table 1** shows the adaptation initiatives and drivers behind these initiatives in Punjab.

4.1 Awareness campaign

The Punjab government has launched an awareness campaign about climate change and agriculture. They have set up a radio station, which gives information to farmers about weather conditions. The station broadcasts multiple programs to increase farmers'

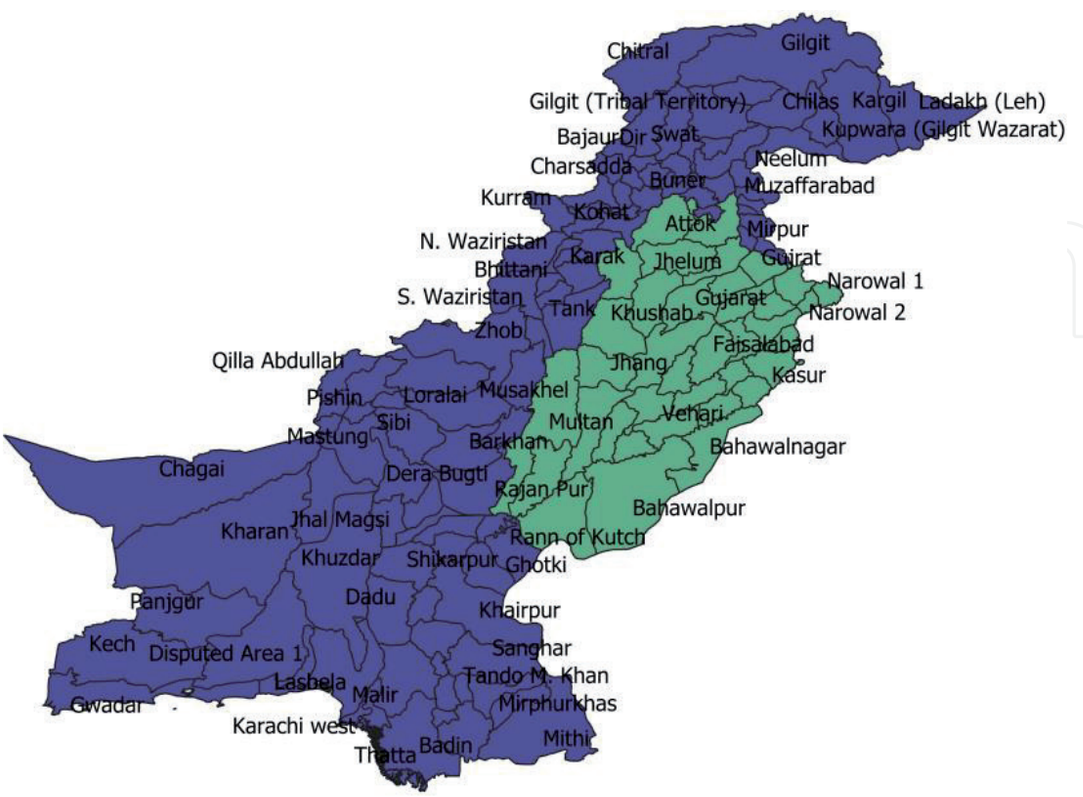

Figure 1.
Map of Pakistan indicating study area.

Numbers	Adaptation initiatives	Drivers behind the initiatives
1	Awareness campaigns	To educate farmers, control damages, improve productivity, linkage with NGOs
2	Training programs for farmers	To expedite implementation, enhance understanding of farmers, to prepare the farmer's community for climate change
3	Research and innovation	Understanding of climate change dynamics, to produce novel techniques
4	Institutional capacity	Effective implementation of climate policies, to address the challenge of lack of professionalism
5	Role of academics	Better research environment, promote climate research, establishment of climate policies with sound scientific backing
6	Departmental coordination	To expedite implementation mechanism, comprehend the situation well in time
7	Autonomous adaptation	Past experiences, knowledge sharing, avoid damages and enhance productivity

Table 1.
Source: The table is created by the authors.

awareness about climate change, its impacts on agriculture sectors and possible strategies to confront the challenge. The impact of this radio station has been positively observed in the province. For example, many farmers are regularly tuning into the radio for information about weather conditions, planning dates, and to know how they will be affected due to climate change. Some of interviewees told us that they are regular listeners of the radio because they get valuable information, such as, climatic conditions, advice about fertilizer use and seeds, and government subsidy schemes for the farmer community. In some programs, climate experts and agro experts among others are invited to discuss climate change, its impacts on agriculture sector and possible solutions. One farmer told us that he regularly follows such programs on Radio because it is helpful to get novel ideas and best practices from agricultural experts.

4.2 Training programs for farmers

The government has set up a formal mechanism to give practical training to the farmers. They arrange sessions with the farmers to teach them based on scientific data how climate change is threatening agriculture sector. Agriculture extension departments which work closely with the farmers at local levels collect data from the fields and gives training to the farmers at local levels. Based on these initiatives, the farmers are able to execute what they learned in their farming practices. For instance, they are advised that they should plant seeds which have been tested in scientific labs and shown to have the capabilities to survive severe weather conditions. It is noted that many trained farmers approached the agriculture extension departments to obtain suitable seeds with respect to weather conditions. We were told by the agriculture extension department in Faisalabad that after attending the training, the farmers' community is encouraged to approach the department for more information about climate change, suitable seeds, solutions for damages due to pests, etc.

The provision of financial help to farmers can be helpful when they are facing financial constraints. On the part of the government, it is providing certain subsidies to the farming community. For example, it provides the farmers with the best seeds and best quality fertilizers keeping in view the exposure of fields to climate change at nominal prices. The farmers' community is also contributing by handling climate change through their adaptation practices.

4.3 Research and innovation

Research and innovation can play a key role in promoting adaptation. Research and innovative techniques are already in place for agriculture adaptation in the province, where experiments have been conducted to find the best varieties of seed that can survive extreme weathers. The government is providing the best varieties of seeds which can survive in hot seasons and produce good results. For instance, the Punjab Seed Corporation is established to provide quality seeds to the farmers according to the conditions of climatic zones in various parts of the province. The subnational government is focusing on research and innovative strategies to address the impacts of climate change. At the institutional level, they are giving training to government officials so that they can comprehend the situation more amicably and address the situation scientifically.

4.4 Institutional capacity and role of academics

Institutional capacity is important for the implementation of any policy, programs or plans. They arrange proper training for the people working in the area of climate change in order to understand the actual scenario, especially the impact assessment of climate change on the agriculture sector in the province. For example, over 150 individuals working in relevant departments in the province are trained in national and international institutions. Many others are encouraged to go abroad and conduct research in area of climate and agriculture sector. It is very likely that well trained staff will play a key role in bringing positive results for effective handling of climate change. Engagement of other stakeholders, especially academics, is another core agenda of government.

Academics in the province are contributing to and conducting studies on climate change and agriculture sector. For example, Agriculture University of Faisalabad has published some work on climate change adaptation and highlighted the importance of adaptation in the province. The university has linkages with international institutions on climate change research. The linkages with international institutions provide opportunities for the professors and researchers at the university to learn innovative adaptation techniques from other parts of the world. They can put into practice in Pakistan the relevant activities they have learned for climate adaptation towards agriculture sector.

4.5 Departmental coordination

Coordination among relevant line departments is essentially important for the implementation of any policy. The subnational government of Punjab has established a link among the 26 agriculture institutes throughout the province in order to set up comprehension strategies for climate change and the agriculture sector. They regularly arrange meetings among these institutes to discuss the new challenges and the existing strategies to manage the negative impacts of climate change. For instance, the Ayub Research Centre (ARC), which manages climate change related activities, is well familiar with what is happening in the agriculture extension departments at various levels and vice versa. By being aware of the activities of agriculture extension departments and others, the ARC can disseminate the positive activities among other institutions and set new targets accordingly.

4.6 Autonomous adaptation and transference of adaptation initiatives

It is noted that the farmers in the province are adjusting to climate change. They are adjusting their agricultural activities with changing climate. In the recent year,

adaptation strategies are being explored by the farmers in many ways. For instance, in Pakistan and Brazil farmers' community is adapting climate change variability by adjustment of planting time and optimization of plant populations [66]. These adjustments are very important adaptation strategies to get the maximum potential of the crops and secure expected productivity. Likewise, the improved and heat tolerant seeds are another important strategy which is being used in Punjab province by the farmers. The development of improved varieties such as early maturing, drought and heat tolerant are necessary to sustain the productivity under changing climate. It is very likely by incorporating such adaptation techniques, the production can increase under moisture stress and extreme temperatures [67]. The autonomous strategies are identified: changing seeds types, changing sowing dates, looking for new fertilizers and planning shade trees. It is the experience; enhance productivity, and knowledge sharing in the farmers' community which encourages them to opt for these adaptation actions.

It is observed that the adaptation strategies are being transferred from one place to another place. They successful strategies are being shared among the farmers' community within the Punjab province and beyond. The successful strategies are applied by other farmers. For instance, a farmer's production was suffering due to rise in temperature. He brought the wheat seed from another place where the temperature was already high; probably these seeds are more heat tolerant. By applying this strategy his production was increased. He shared his practice with other farmers in the area so they also started the same practice and that was quite successful. These strategies are not only limited to the Punjab province but it is also reported that the successful adaptation initiatives either they are planned or autonomous are replicated in other province. For instance, the framers in the Khyber Pakhtunkhwa (KPK) with bordering area of Punjab province are learning the successful stories from Punjab farmers and replicated in their areas in the KPK. This is again shared and transferred within the farmers' community in the KPK. Therefore, it is concluded that the adaptation initiatives in Punjab province is not only limited and transferred within Punjab province but also transferred and implemented in other areas and provinces. Despite all these efforts, there are certain challenges as well.

4.7 Key challenges

Despite these promising initiatives the province and local farmers are facing some key challenges for the effective adaptation to climate change. The data indicates that the major hurdles are in the form of a lack of institutional and human capacity, scarcity of financial resources, a lack of technological advancement, lack of research and innovation, and a weak integration of adaptation policy with other related policies. On the other hand the local farmers face lack the awareness about climate change, weak capacity building, financial constraints, and technicality issues to opt with adaptation measures.

5. Conclusion

Climate change adaptation in the agriculture sector is considered a striking strategy to manage the impacts of climate change. Theoretically, climate change adaptation is a new field and it creates a space for experimentation and new forms of governance. In recent years, subnational governments have shown that they have an effective role in dealing with climate change. The subnational government Punjab is firmly committed to addressing the challenge of climate change.

This study has found that the province is actively dealing with the consequences of climate change. They have been taking initiatives for climate adaptation for the agriculture sector in the province. The government has launched a major awareness campaign in the province. Moreover, institutional capacity enhancement, promotion of climate change research, establishment of linkage with academics, enhancement of capacity building, and involvement of farmers' community in climate adaptation for agriculture sectors are some of other important steps taken by Punjab province. It is pointed out that autonomous adaptation is also taking place in the province. The identified autonomous adaptation practices include changing planting dates, changing crops types, changing fertilizers, and planting shade trees. Our study identified the drivers behind planned and autonomous level adaptation. These differences at planned level adaptation are primarily driven by coordination among the respective departments, engagement with academics, and availability of financial resources. On the other hand, autonomous initiatives of the province are mainly driven by the previous experiences of farmers, sustainability in agriculture production, and knowledge sharing. The study found that the adaptation strategies are being transformed from one place to another place within the province and outside the province. This transformation is happening by successful experience sharing among the farmer community. Moreover, the study identified key challenges for adaptation to climate change in the province. These challenges are in the form of lack of institutional and human capacity, scarcity of financial resources, lack of research and innovation, and integration of adaptation policy with other related policies.

Conflicts of interest

The authors declared no conflict of interest in this manuscript.

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References

[1] Walker BJA, Adger WN, Russel D. Institutional barriers to climate change adaptation in decentralised governance structures: Transport planning in England. Urban Studies. 2014;**52**:1-16

[2] Lemos MC, Agrawal A, Eakin H, Nelson DR, Engle NL, Johns O. Building adaptive capacity to climate change in less developed countries. In: Asrar GR, Hurrell JW, editors. Climate science for serving society: Research, modeling and prediction priorities. The Netherlands: Springer, Dordrecht; 2013. pp. 437-457. DOI: 10.1007/978-94-007-6692-1_16

[3] Salik KM, Ishfaq S, Saeed F, Noel E, Syed Q. Pakistan: Country situation assessment. Islamabad: Sustainable Development Policy Institute; 2015

[4] Rasul G, Ahmad B. Climate Change in Pakistan. Focused on Sindh Province, Pakistan Meteorof Logical Department Report. 2012

[5] Banoori W. Pakistan: Climate Report. 2012. Available from: http://www.thefrontierpost.com/article/163613

[6] Rasmussen B, Allen S, Rasmussen ZA, Bajwa R. Learning from disasters to save lives every day in Pakistan. Lancet. 2013. DOI: 10.1016/S0140-6736(13)60652-2. Available from: https://www.ncbi.nlm.nih.gov/pubmed/23684253

[7] Kreft S, Eckstein D. Global Climate Risk Index 2014. Bonn: Germanwatch; 2013

[8] Shakoor U, Saboor A, Ali I, Mohsin AQ. Impact of climate change on agriculture: Empirical evidence from arid region. Pakistan Journal of Agricultural Sciences. 2011;**48**:327-333

[9] Janjua PZ, Samad G, Khan NU, Nasir M. Impact of climate change on wheat production: A case study of Pakistan. The Pakistan Development Review. 2010;**49**:799-822

[10] Abid M, Scheffran J, Schneider UA, Ashfaq M. Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province. Pakistan Earth System Dynamics. 2015;**6**:225

[11] Go P. Pakistan Economic Survey 2015-2016. Islamabad: Ministry of Finance, Government of Pakistan. 2016. Available from: http://www.finance.gov.pk

[12] TDAP. Statistics for 2015-2016. Islamabad: Trade Development Authority of Pakistan (TDAP). 2016. Available from: http://www.tdap.gov.pk/tdap-statistics.php

[13] Noman MA, Schmitz M. Economic assessment of the impact of climate change on the agriculture of Pakistan, business econ. Horizons. 2011;**4**:1-12

[14] Abid M, Schneider UA, Scheffran J. Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan. Journal of Rural Studies Part A. 2016;**47**:254-266

[15] Wilson E. Adapting to climate change at the local level: The spatial planning response. Local Environment: The International Journal of Justice and Sustainability. 2006;**11**(6):609-662

[16] Biesbroek GR, Swart RJ, van der Knaap WGM. The mitigation-adaptation dichotomy and the role of spatial planning. Habitat International. 2009;**33**(3):230-237

[17] Adger WN et al. Are there social limits to adaptation to climate change? Climatic Change. 2009;**93**:335-354

[18] Smit B, Wandel J. Adaptation, adaptive capacity and vulnerability.

Global Environmental Change-Human and Policy Dimensions. 2006;**16**:282-292. DOI: 10.1016/j.gloenvcha.2006.03.008

[19] Nyong A, Adesina F, Elasha BO. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation Strategies in Global Change. 2007;**12**:787-797

[20] Porter J, Demeritt D, Dessai S. The right stuff. Informing adaptation to climate change in British local government. SRI Papers. 2014;**76**:1-30

[21] Rijke J, Brown R, Zevenbergen C, Ashley R, Farrelly M, Morison P, et al. Fit-for-purpose governance: A framework to make adaptive governance operational. Environmental Science and Policy. 2012;**22**:73-84

[22] Puppim de Oliveira JA. The implementation of climate change related policies at the subnational level: An analysis of three countries. Habitat International. 2009;**33**:253-259

[23] Di Falco S. Adaptation to climate change in sub-Saharan agriculture: Assessing the evidence and rethinking the drivers. European Review of Agricultural Economics. 2014;**41**(3):405-430

[24] IPCC. Fifth Assessment Report. Cambridge: Cambridge University Press; 2014

[25] Kpadonou RAB, Adégbola PY, Tovignan SD. Local knowledge and adaptation to climate change in Ouémé valley, Benin. African Crop Science Journal. 2012;**20**(2):181-192

[26] Füssel H-M. Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. Sustainability Science. 2007;**2**:265-275

[27] Burton I, Diringer E, Smith J. Adaptation to Climate Change: International Policy Options. Arlington, VA: Pew Center on Global Climate Change; 2006

[28] Kurukulasuriya P, Rosenthal S. Climate Change and Agriculture. World Bank Environment Department Paper 91. 2003

[29] McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, editors. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press 2001. pp. 877-912

[30] United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto protocol to the UNFCCC. In: UNFCCC, Report of the Conference of the Parties Third Session. Kyoto: UNFCCC; 1998. pp. 4-29

[31] Mizina SV, Smith JB, Gossen E, Spiecker KF, Witkowski SL. An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. Mitigation and Adaptation Strategies for Global Change. 1999;**4**:25-41

[32] Stern N. The economics of climate change. In: The Stern Review. 2006. https://www.brown.edu/Departments/Economics/Faculty/Matthew_Turner/ec1340/readings/Sternreview_full.pdf

[33] Selvaraju R, Subbiah AR, Baas S, Juergens I. Livelihood Adaptation to Climate Variability and Change in Drought-Prone Areas of Bangladesh. Developing Institutions and Options; 2006. http://www.fao.org/3/a-a0820e.pdf

[34] Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. Progress in Development Studies. 2003;**3**:179-195

[35] Smit B, Skinner MW. Adaptation options in agriculture to climate change:

A typology. Mitigation and Adaptation Strategies for Global Change. 2002;**7**(1):85-114

[36] United Nations Framework Convention on Climate Change (UNFCCC). United Nations Framework Convention on Climate Change. Text, Geneva: World Meteorological Organization and United Nations Environment Program; 1992

[37] UNFCCC Climate Change Country Parties Discuss Approaches to Reduce Emissions From Deforestation in Developing Countries. 2007. unfccc.int/press/news_room/newsletter/in_focus/items/3944.php

[38] Dessai S, Lu X, Risbey JS. On the role of climate scenarios for adaptation planning. Global Environmental Change. 2005;**15**(2):87-97

[39] Ali A. Erenstein O. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Climate Risk Management. 2017;**16**:183-194

[40] Mumtaz M. The National Climate Change Policy of Pakistan: An evaluation of its impact on institutional change. Earth Systems and Environment. 2018;**2**:525-535

[41] Leng G, Huang M. Crop yield response to climate change varies with crop spatial distribution pattern. Scientific Reports. 2017;**7**:1463

[42] Hatfield JL, Boote KJ, Kimball BA, Ziska LH, Izaurralde RC, Ort D, et al. Climate impacts on agriculture: Implications for crop production. Agronomy Journal. 2011;**103**:351-370. DOI: 10.2134/agronj2010.0303

[43] Preston BL, Suppiah R, Macadam I, Bathols J. Climate change in the Asia/Pacific region. In: A Consultancy Report Prepared for the Climate Change and Development Roundtable. Aspendale Australia: CSIRO Marine and Atmospheric Research; 2006

[44] Asian Development Bank (ADB). The Economics of Climate Change in Southeast Asia: A Regional Review. Manila: Asian Development Bank; 2009. https://www.adb.org/sites/default/files/publication/29657/economics-climate-change-se-asia.pdf

[45] Paul E, Ernsting A, Semino S, Gura S, Lorch A, Agriculture and climate change: Real problems, false solutions. In: Grupo de Reflexión Rural, BiofuelsWatch, EcoNexus. Oxford, UK: The Development Fund Norway and NOAH; 2009

[46] Siddiqui R, Samad G, Nasir M, Jalil HH. The impact of climate change on major agricultural crops: Evidence from Punjab, Pakistan. The Pakistan Development Review. 2012;**51**:261-276

[47] TFCC—Task Force on Climate Change: Planning Commission, Government of Pakistan. Available from: http://pc.gov.pk/usefull_links/Taskforces/TFCC_Final_Report.pdf

[48] Ali S, Liu Y, Ishaq M, Shah T, Ilyas A, Din IU. Climate change and its impact on the yield of major food crops: Evidence from Pakistan. Food. 2017;**6**(6):39

[49] Tubiello FN, Fischer G. Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000-2080. Technological Forecasting and Social Change. 2007;**74**:1030-1056

[50] Jörgensen K, Jogesh A, Mishra A. Multi-level climate governance and the € role of the subnational level. Journal of Integrative Environmental Sciences. 2015;**12**:235-245. DOI: 10.1080/1943815X.2015.1096797

[51] Roppongi H, Suwa A, Puppim De Oliveira JA. Innovating in sub-national climate policy: The mandatory emissions reduction scheme in Tokyo. Climate Policy. 2017;**17**(4):516-532

[52] Jörgensen K. Climate Initiatives at the Subnational Level of the Indian States and their Interplay with Federal Policies. 2011. https://www.polsoz.fu-berlin.de/polwiss/forschung/systeme/ffu/publikationen/2011/11_joergensen_montreal/isa11_joergensen_draft.pdf

[53] Jänicke M. The multi-level system of global climate governance—The model and its current state. Environmental Policy and Governance. 2017;**27**(2):108-121

[54] Davoudi S, Crawford J, Mehmood A. Planning for Climate Change: Strategies for Mitigation and Adaptation for Spatial Planners. London: Earthscan/James and James; 2009

[55] Jordan R, Birkin M, Evans A. Agent-Based Modelling of Residential Mobility, Housing Choice and Regeneration. Netherlands: Springer; 2012

[56] Termeer CJAM, Dewulf ARPJ, Rijswick HFMW, van Buuren A, van Huitema D, Meijerink S, et al. The regional governance of climate adaptation: A framework for developing legitimate, effective and resilient governance arrangements. Climate Law. 2011;**2**(2):159-179

[57] Eakin H, Lemos MC. Adaptation and the state: Latin America and the challenge of capacity-building under globalization. Global Environmental Change. 2006;**16**:7-18

[58] Bulkeley H, Newell P. Governing Climate Change. New York: Routledge; 2010

[59] Lindseth G. The cities for climate protection campaign (CCPC) and the framing of local climate policy. Local Environment. 2004;**9**(4):325-336

[60] Moser SC, Luers AL. Managing climate risks in California: The need to engage resource managers for successful adaptation to change. 2008. https://link.springer.com/article/10.1007/s10584-007-9384-7

[61] Ahmed H, Khan MR, Panadero-Fontan R, Lopez-Sández C, Iqbal MF, Naqvi SMS, et al. Geographical distribution of hypodermosis (*Hypoderma* sp.) in northern Punjab, Pakistan. Kafkas Universitesi Veteriner Fakultesi Dergisi. 2012;**18**:A215-A219

[62] Abid M, Ashfaq M, Hassan S, Fatima N. A resource use efficiency analysis of small of cotton farmers in Punjab, Pakistan. Pakistan Journal of Agricultural Sciences. 2011;**48**:65-71

[63] Badar H, Ghafoor A, Adil SA. Factors affecting agricultural production of Punjab (Pakistan). Pakistan Journal of Agricultural Sciences. 2007;**44**:3

[64] PBS—Pakistan Bureau of Statistics: Agricultural Statistics of Pakistan. Government of Pakistan, Statistics Division, Pakistan Bureau of Statistics. 2011. Available from: http://www.pbs.gov.pk/content/agricultural-statistics-pakistan-2010-11 [Accessed: 1 August 2014]

[65] Hanif U, Syed SH, Ahmad R, Malik KA, Nasir M. Economic impact of climate change on the agricultural sector of Punjab [with comments]. The Pakistan Development Review. 2010:771-779. http://www.pide.org.pk/pdf/PDR/2010/Volume4/771-798.pdf

[66] Ali A, Erenstein O. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Clinical Risk Management. 2017;**16**:183-194

[67] Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change. 2009;**19**:248-255